pointed out can exist as an irrotational one without reaction in MacCullagh's medium. This same observation of course applies to Dr. Boltzmann's analysis, the difference being that vortex rings would be rings of magnetic current instead of electric current, and atoms would act like electric diads instead of elementary magnets. The existence of unclosed lines of electric vector, however, seems to make this simple interpretation of Dr. Boltzmann's analysis impossible, and as we cannot in general substitute whirl for flow in fluid motion, the vortex ring analysis could not be applied if Dr. Boltzmann's electric vector were interpreted as a whirl; and hence Mr. Larmor's investigation seems confined to the interpretation he has given.

Having assumed that the medium is such as to react elastically against curl of the tonus (τ), and his fundamental equations thus being—

$$(1),\ E=\dot{\tau}\ ;\ (3),\ T=K/8\pi\ .\ E^2$$
$$(2),\ H=\text{curl}\ \tau\ ;\ (4),\ V=\nu/2\ .\ H^2$$

he proceeds to deduce the equation corresponding to (2), namely, (5)$K\dot{E}=\text{curl}\ H$ by applying Hamilton's principle to $T-V$ in a way which is well known. He now remarks that in accordance with his dynamical principles $K\dot{E}$ is rate of change of momentum, and he adds to curl H any external impressed forces, which he divides into two classes: (1) those due to reversible causes, such as electromotive of contact, chemical action, &c. (F); and (2) those due to irreversible causes, such as ohmic resistance, &c., which are proportional to the electric vector, and thus obtains this equation in the form

$$KE=\text{curl}\ H-4\pi C\ (E+F)$$

It would thus seem as if the electric conduction current were a different thing from a changing electric displacement, though both depending on curl H. This arises from the difficulty noticed above, and seems to require careful consideration. By judicious theories as to the function of the matter in stopping the continual acceleration without uncurling the H, the difficulty can be surmounted. In order to get over all the difficulties of discontinuities at the surfaces of bodies, Dr. Boltzmann assumes that the properties of the ether vary rapidly but continuously in passing across a surface, so that he can assume that these equations apply everywhere.

Depending on his dynamical basis, Dr. Boltzmann has obtained the following dimensions for electromagnetic quantities, which, of course, differ entirely from both the electric and magnetic systems of units—

$$[E]=[LT^{-1}],\ [K]=[ML^{-3}]$$
$$[H]=[ML^{-1}T^{-2}]\,{}^{*}\quad [\mu]=[M^{-1}LT^{-2}]$$

After a short discussion as to the possibility of founding the science upon a purely analytical basis, by assuming equations and showing that they lead to true results, which is the basis of Hertz's method, and a short criticism of this method as applied by Hertz, Dr. Boltzmann proceeds to show how the old equations of action at a distance and von Helmholtz's work are connected with Maxwell's view of the subject. His treatment of superficial effects by means of a rapid variation of structure of the ether at the surface of solids, seems essentially the same as Mr. O. Heaviside has advocated in opposition to von Helmholtz's double electric layers. All this analytical method is, of course, necessary and interesting in what may be called a transition work, one that concerns those who have been brought up under one school of thought and are entering another; a sort of epistle to the Hebrews, a college between youth and manhood. It concerns the past rather than the future, towards which we should press, forgetting those things that are behind.

Although Dr. Boltzmann has left out all embellishments, he has had pity on his readers. There are necessarily included in a transition work of this kind innumerable formulæ, of which 168 are frequently referred to, and these he has collected into two folding sheets, each of five folds, at the end of his work. This is most considerate. Books dealing with many formulæ might well follow suit, although it certainly is a little terrifying to have 168 formulæ presented as the outcome of the book in a way that necessarily attracts the attention of anyone who thinks of reading it. Those who are frightened by this should, however, recollect that the whole subject of electromagnetism depends on only four very simple equations. Dr. Boltzmann would have much simplified his work if he had adopted any vector symbolism.

It is to be hoped that this part of Dr. Boltzmann's work, as well as the former part, will soon be translated, and so made easily accessible to English students. The work of a great master, the product of a great mind, helps all men who can understand it.

THE STORY OF THE SUN.

The Story of the Sun. By Sir Robert Ball, LL.D. (London: Cassell and Co., 1893.

THERE is no more interesting chapter in science than that which deals with our great central luminary. Its story has been gradually gaining in interest since the first application of the telescope to its study by Galileo, and since the advent of the spectroscope our knowledge of solar phenomena has advanced by leaps and bounds. At the present time the scrutiny of the sun is more minute and continuous than ever, and the constant acquisition of fresh information sufficiently explains the need for additional works on the subject, or for new editions of old ones.

The author of the book before us does not approach the subject as a practical investigator in this branch of astronomy, and his efforts are therefore chiefly intended for the delectation of that class of readers for which he chiefly caters. The first thing that strikes one on glancing through the pages of the book is the great variety of the matter which it contains, and one begins to wonder if he has mistaken the title of the volume. It is not too much to say that nearly every department of astronomical inquiry is touched upon more or less; from the determination of the polar flattening of the earth to the photography of minor planets and the appearances of nebulæ. Though the author never seems at a loss to give reasons for the introduction of matter apparently not at first sight connected with the subject in hand, his reasons frequently appear to be nothing more than excuses for filling so many pages. For example, we fail to see the necessity

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[*] This is misprinted in the text, but right in the table of formulæ at the end of the book.

of devoting a whole chapter to the members of the solar system, or a large part of a chapter and a full-page plate to eclipses of the moon; again, the discussion of the Glacial Period surely belongs more to the story of our own planet than to that of the sun, and might very well have been omitted.

This method of treatment is the more objectionable as it has evidently involved the omission of reference to many observations of great interest, and must inevitably tend to give the impression that our knowledge is very much less than it is in reality. At the same time it does an injustice alike to the reader, and to the army of workers who devote their energies to the pursuit of this branch of knowledge.

Again, the story of the sun would certainly lose none of its charm by historical treatment, but we look in vain for even the barest mention of the names of Ångström, Thalén, Faye, Cornu, Perry, Balfour Stewart, and a host of other workers who have taken so great a part in solar inquiries.

So far as it goes, however, the story of the sun is told in that fascinating way which has deservedly brought the author fame, and our greatest cause of complaint is that it does not go far enough. The first five chapters, occupying nearly one-third of the book, deal with the solar system, the sun's distance, and the sun's mass. In these well-worn subjects there is nothing new to tell and little scope for novelty, but occasionally we come across some of the bright illustrations at which the author is so expert; as, for instance, the endeavour to impress the reader with the magnitude of the velocity of light.

In chapter vi. a fair account is given of the total amount and spectroscopic analysis of the "light of the sun." A coloured plate of the solar spectrum is of unusual excellence, but many of the finer details of Mr. Higgs's photographic spectrum are lost in the reproductions, and scarcely do justice to the originals.

After a chapter on the causes of eclipses, we come to one on sun-spots, and here we first find evidence of the incompleteness to which reference has been made. The appearances presented by spots are fully described and illustrated by a most liberal allowance of diagrams, but no mention is made of "veiled spots." The rate of solar rotation is discussed in considerable detail, but if the spectroscopic results are to be mentioned at all, Dunér's observations might have found a place alongside those of Mr. Crew. The author seems to favour the idea that the varying rotation of the photosphere in different latitudes is produced by the friction of concentric shells of the matter of which it is formed; other views, not less probable, are utterly ignored; as, for instance, one which follows from the theory that spots are formed by downrushes of cool vapours—an explanation which Sir Robert Ball has adopted as the most probable. The reader is also left in blissful ignorance of the fact that astronomers have taken the trouble to make a minute study of the spectra of sunspots, although this work has been going on continuously for the last fifteen years, chiefly at Kensington and Stonyhurst. Of the existence of the Committee on Solar Physics, and of the continuous photographic record of the spots which it has organised, the author seems to have no knowledge. Even the importance of the eleven-yearly period does not appear to be clearly grasped, and only the very briefest references are made to this fundamental solar unit.

The chapter on solar prominences contains most of the ordinary information on the subject, and has the merit of including some of the most recent observations by Trouvelot and Fenyi. In addition, Prof. Hale's remarkable work in photographing these objects is considered in some detail. Very little attempt is made, however, to distinguish between quiet and eruptive prominences.

The solar corona is dismissed in very few words, and the illustrations have not been well chosen. In giving a somewhat detailed account of the American expedition to French Guiana to observe the eclipse of December 1889, it would have been gracious to record the fact that it was during an expedition to this place at the same time that the late Father Perry met with his fate. The author's estimate of our spectroscopic knowledge of the corona is very low, and it is disposed of in twenty lines; but this meagre description is due to the fact that the most recent observations referred to are those made by Janssen in 1871!

It has been well remarked that "hypothesis is the soul of investigation," but our author makes no attempt to give a full or complete account of any theory; apparently on the ground that we are still so "very ignorant concerning the actual physical nature of the great luminary." The principal point of theory touched upon is that which concerns the materials of which the photosphere is composed, the ordinary view that it consists of glowing clouds being accepted. Working on the lines of a suggestion made by Dr. Johnstone Stoney in 1867, the author argues in favour of the view that to carbon "belongs the distinction of being the main source whence sunlight is dispensed." (p. 289.) This certainly seems as probable as the generally accepted idea that the photosphere consists of liquid metals, but it does not give us any further insight into the causes of the various phenomena which are observed. The study of the circulation of the sun's atmosphere will no doubt eventually furnish the key to most of the problems of solar physics; but here our author leaves us, with nothing more than an unexplained diagram illustrating a theory of the solar currents.

Of the chapter dealing with solar and magnetic phenomena, we have only to note that the author repeats the mistake with reference to the Carrington-Hodgson outburst—a subject which has already been discussed in these columns. He makes a suggestion, however, which may be well worth consideration, namely, that the solar and magnetic disturbances may not stand in the relation of cause and effect at all, but are each of them "manifestations of some other influence of electromagnetic waves on a vast scale sweeping through our system, and influencing the magnetic phenomena in the various bodies of which our system is composed." (p. 234).

We see the author at his best in the next three chapters, discussing step by step the probable cause of the maintenance of solar radiation. The somewhat difficult subject of molecular physics no longer remains obscure under the influence of his luminous exposition, and their application to the sun will be clear to any intelligent reader. This part of the subject is only marred by the false analogy with Nova Aurigæ, which is pointed out as suggesting a possible original source of the sun's heat. We should have imagined that phenomena which last only for a few weeks, must be vastly different from those which continue for millions of years.

From one point of view the discourse on "the sun as a star" is excellent. It is certainly interesting to know that the sun is only one of many millions of stars, that it does not travel so quickly in space as 1830 Groombridge; or again, that it is a certain number of times less massive than Arcturus; but not less interesting is the study of its physical relation to the other stars—what stars it may have resembled in the past, and what it will probably resemble in the future. On this latter question much light has been thrown by recent work on stellar and nebular spectra, with which we cannot but suppose the author to be familiar. The whole of this great problem, however, is discussed in little more than a page of text and a page of *drawings* of stellar spectra, on various scales, to which no direct reference is made. The fact that carbon plays such a prominent part in the absorption spectra of one group of stars is not mentioned, and the author seems to have utterly failed to see the significance of it in relation to the presence of carbon in the sun, of which he makes so much in another chapter. From the evolutionary point of view this is obviously a fact of the first importance, indicating that as the sun goes on cooling the carbon absorption will increase until finally its spectrum will resemble that of such stars as 152 Schjellerup. The presence of a plate illustrating various nebulæ led us to suppose that we should be treated to the story of the sun's probable growth from the nebulous stage, but we were disappointed to find that they were only intended to indicate that our sun is but one of a myriad host of stars!

Sir Robert Ball's views of the cause of the Ice Age, which have already been discussed in NATURE, are very clearly set forth, and he maintains that "it is impossible to doubt the truth of the main factors in the astronomical theory of the cause of Ice Ages" (p. 319).

The final chapter, on "the movements of the solar system," is an excellent exposition of the method by which the direction of the sun's motion in space is ascertained.

We may perhaps repeat that the story of the sun is told admirably so far as it is told at all, but we regret to find that so many solar inquiries of the greatest interest have not had the great benefit of description by the author's graphic pen.

We have nothing but praise for the excellence of the majority of the plates and diagrams, and the printing is also bold and clear.

A. FOWLER.

THE LEPIDOPTERA OF THE ATLANTIC ISLANDS.

The Butterflies and Moths of Teneriffe. By A. E. Holt White. Edited by Rashleigh Holt White, Vice-President of the Selborne Society. Illustrated from the Author's Drawings. (London: L. Reeve and Co., 1894.)

THE coleopterous fauna of the Atlantic Islands has been well worked by the late Mr. Wollaston, but as regards the *Lepidoptera*, the only obtainable information has been either from large books (which rarely supply complete or detailed information) or detached papers, some of them very valuable, but not always easily accessible.

Consequently, when Mrs. Holt White, the wife of one of the descendants of a brother of Gilbert White, spent the winter of 1892-93 in Teneriffe for the benefit of her health, and occupied herself with the collecting and rearing of butterflies and moths, she could find no available information on the subject, and bravely resolved to do her best to supply the want. The result is the little book before us, which, though making no pretensions to be otherwise than popular, will yet be most useful to scientific entomologists, by supplying them with detailed descriptions and fairly good figures (though the first plate of the four strikes us as being somewhat coarsely coloured) of nearly all the larger *Lepidoptera* of a very interesting, though very limited fauna. One moth is described as new, and others are now figured for the first time.

A striking feature of the Atlantic Islands is the extreme poverty of their lepidopterous fauna. Our British *Lepidoptera* are considered few; but we can at least point to upwards of 2000 species; and even Iceland, though possessing no indigenous butterflies, boasts of nearly as many moths as Madeira or Teneriffe. Several causes combine to produce the scarcity of *Lepidoptera* in the Atlantic Islands. They are islands, far from the mainland, and on the extreme limits of the faunas to which they respectively belong. The native flora has in some places almost disappeared, and with it, of course, the insects dependent on it. How far the present insects of the islands are endemic, it is difficult to say. Some are certainly peculiar to the islands; the bulk of the species of the northern islands are European, or representative of European species; one or two are American, but whether introduced, or whether remnants of an outlying American fauna, it is at present impossible to say; and stranger still, one or two are East Indian in their affinities, and are not species likely to have been introduced by accident. The best representatives of the last two classes are *Pyrameis huntera* and *P. callirhoë*.

The six principal groups of Atlantic islands from north to south are the following: the Azores, Madeiras, Canaries, Cape Verdes, Ascension, and St. Helena. Of the *Lepidoptera* of the Cape Verdes and Ascension very little is recorded, and we need say no more of them in this place.

The Azores lie further to the north and west than any of the other groups. Mr. Godman's "Natural History of the Azores" (1880) is our latest authority on the *Lepidoptera*. He enumerates nine butterflies and twenty-eight moths, all British, except the North American *Danais archippus*, and the South European *Hypena obsitalis*. It is worthy of remark that the typical *Pieris brassicas* occurs in the Azores, instead of the allied *P. Wollastoni*, which occurs both in the Madeiras and Canaries, or *cheiranthi*, which is confined to the Canaries. *P. Wollastoni*, we may here note, much resembles the North Indian *P. nipalensis*.

In the *Transactions* of the Entomological Society for 1891, Mr. Bethune-Baker published "Notes on the *Lepidoptera* collected in Madeira by the late T. Vernon